

CORRESPONDENCE

Research Letter

The Impact of Commonly-Worn Face Masks on Physiological Parameters and on Discomfort During Standard Work-Related Physical Effort

In view of the pandemic spread of SARS-CoV-2, there is increasing evidence that face masks should be worn in public spaces as an integral part of hygiene measures to contain the virus (1). Currently, the most common face masks are FFP2 masks (suitable for self-protection), surgical masks, and cloth masks (“community masks”) that are often used in the non-clinical setting. With their increasing use among the general population, more reports have suggested that mask wearing presents a health risk (2–4). In contrast to their effectiveness in infection prophylaxis, the effects of the above mask types on physiological parameters (blood gases, vital parameters) and the subjective perception of exertion under workload conditions have not yet been systematically investigated.

Methods

Voluntary study participants (N = 26) from the hospital staff first had one minute without exercise (baseline) and then performed tests of exertion at work-typical levels (50/75/100 watts, for three minutes each, in direct succession), wearing the different face masks (cloth, surgical, or FFP2) or no mask, to measure changes in blood gases (transcutaneous carbon dioxide partial pressure [$P_{tc}CO_2$], pulse oximeter-derived oxygen saturation [SpO_2]), and vital parameters (heart rate, respiratory rate, and arterial blood pressure; recorded non-invasively). The order of mask wearing was different and randomized from person to person. A five- to ten-minute rest period was given at each mask change.

The measured parameters were compared with the subjective perceived exertion (Borg’s scale [with 6 points corresponding to “very, very light”, and 20 points corresponding to “very, very difficult”]) and clinical characteristics (age, body mass index [BMI], sex, nicotine use, and hypertension). In order to detect potential pulmonary limitations, spirometry was performed at rest before the experiment was carried out. In addition, mask-related main symptoms during exercise were recorded. Mask-specific group differences were determined using one-way analysis of variance. The Pearson correlation coefficient was used for parametric distribution. This study received ethics approval from the ethics committee of the Medical School Brandenburg (E-01–20200527).

Results

Overall, 24 of the participants finished all conditions and were included with complete data. Independent of the mask type, two participants had to stop the assessment prematurely due to muscular exhaustion or joint problems. Based on the participant characteristics (age 44.7 ± 11.7 years; 46% male; BMI 25.4 ± 4.3 ; 26.9% smoker; 19.2% with arterial hypertension; FEV1 / FVC $101.6 \pm 7.4\%$) as well as diversity in areas of work and fitness levels, a good cross-section of the hospital workforce can be assumed.

During exercise, the $P_{tc}CO_2$ (which corresponds to arterial CO_2 partial pressure) increased more distinctly for all three mask types as compared to exercise without a mask (100 watts: factor 2.7 with a FFP2 mask; factor 2.2 with a surgical mask; factor 1.8 with a cloth mask; $p < 0.001$ each). At 100 watts, the SpO_2 levels fell more sharply while wearing the FFP2 mask than during exercise with no mask (-1.54% versus -0.71% ; $p = 0.005$) (Table). No mask-specific changes were observed for vital parameters. The subjective perception of exertion was on average highest while wearing the FFP2 mask (14.6 points on the Borg scale), and lowest while wearing no mask (11.9 points). A high perception of exertion correlated across all mask types (FFP2 / surgical / cloth) with a higher heart rate ($r = 0.737 / 0.752 / 0.641$; $p = < 0.001 / < 0.001 / 0.002$, respectively) and respiratory rate ($r = 0.463 / 0.510 / 0.503$; $p = 0.023 / 0.011 / 0.012$, respectively), but it did not correlate with levels of increased CO_2 ($r = -0.026 / -0.260 / -0.380$; $p = 0.903 / 0.220 / 0.080$, respectively). No relevant correlations were observed for clinical characteristics or resting spirometry measures.

During bicycle ergometry, 14 out of 24 participants reported mask-specific discomfort (dyspnoea, $n = 11$; headache, $n = 4$; feeling hot, $n = 2$; dizziness, $n = 1$); 13 of these 18 discomfort reports (72%) were related to FFP2 masks.

Discussion

During exertion, wearing a commonly-used face mask led to measurable but clinically irrelevant changes in blood gases as compared to not wearing a mask. The mask-specific absolute differences for $P_{tc}CO_2$ / SpO_2 were small (maximum 4.3 mmHg / -1.54% while wearing a FFP2 mask). In addition, the described symptoms when wearing each type of mask did not correlate with the levels of the exercise-related increases in CO_2 or drop in SpO_2 , but did correlate with increases in respiratory and heart rates. A critical threshold for clinically significant hypercapnia/hypoxemia is not defined in the current guidelines as it differs greatly between individuals and depends on the respective baseline value. In general, perceived changes in healthy individuals are only to be expected from $PaCO_2$ values > 60 mmHg (5), although even minor increases in $PaCO_2$ due to cerebral vasodilation can cause headaches. Based on our data, it is not possible to identify risk groups for whom wearing a mask in everyday working life would have particularly negative effects. Nevertheless, it seems reasonable that people with chronic respiratory diseases should use FFP2 masks with caution, as clinically significant changes in pO_2 and pCO_2 values have been reported for this group with mask use (3). In particular, less trained people (fast increase in heart rate) seem to experience symptoms such as dyspnoea, headaches, feeling hot, or dizziness with all mask types, especially with the FFP2 mask, sometimes independent of the grade of exertion. Based on the relationship shown between

TABLE

Mean values and standard deviations for the mask-specific changes in the examined parameters during exertion

						p-values		
						No vs. cloth	No vs. surg.	No vs. FFP2
Transcutaneous CO ₂ partial pressure (mmHg)	Baseline	36.8 ± 3.0	36.3 ± 3.8	36.4 ± 3.8	36.2 ± 4.0	0.440	0.581	0.290
	50 W	38.0 ± 3.2	38.3 ± 4.1	38.7 ± 4.0	38.6 ± 4.5	0.003	<0.001	<0.001
	75 W	38.8 ± 3.4	39.2 ± 4.0	39.6 ± 4.1	39.7 ± 4.6	0.002	<0.001	<0.001
	100 W	38.4 ± 4.3	39.1 ± 4.9	39.9 ± 4.9	40.5 ± 4.9	<0.001	<0.001	<0.001
Peripheral O ₂ saturation (%)	Baseline	98.7 ± 0.8	98.9 ± 0.5	98.9 ± 0.8	98.9 ± 0.7	0.257	0.257	0.135
	50 W	98.2 ± 0.9	98.3 ± 0.7	98.3 ± 0.7	98.3 ± 1.0	0.575	0.539	0.543
	75 W	98.2 ± 0.8	98.1 ± 0.9	98.3 ± 0.8	98.0 ± 0.7	0.266	0.503	0.022
	100 W	98.0 ± 0.8	98.0 ± 1.1	97.9 ± 1.2	97.4 ± 1.4	0.447	0.247	0.005
Breathing frequency (n/min)	Baseline	14.8 ± 2.2	16.0 ± 3.0	14.8 ± 2.2	15.3 ± 2.2	0.042	0.848	0.340
	50 W	21.5 ± 3.8	22.0 ± 2.9	21.4 ± 4.1	21.4 ± 4.2	0.398	0.934	0.595
	75 W	25.3 ± 5.1	25.2 ± 5.1	24.8 ± 5.1	24.3 ± 6.8	0.258	0.732	0.334
	100 W	26.4 ± 6.1	29.2 ± 8.4	28.2 ± 8.5	29.0 ± 9.8	0.195	0.121	0.116
Heart rate (n/min)	Baseline	79.4 ± 15.6	79.4 ± 12.7	80.0 ± 13.7	79.3 ± 14.4	0.984	0.746	0.978
	50 W	103.5 ± 16.3	103.4 ± 16.5	102.9 ± 17.1	104.6 ± 18.1	0.939	0.482	0.373
	75 W	117.8 ± 22.5	117.8 ± 21.7	117.1 ± 21.8	119.6 ± 23.8	0.978	0.293	0.312
	100 W	129.8 ± 25.1	131.5 ± 25.2	130.0 ± 26.0	132.1 ± 26.9	0.433	0.787	0.174
Systolic RR blood pressure (mmHg)	Baseline	127.8 ± 14.6	130.1 ± 18.2	129.5 ± 15.1	126.7 ± 16.1	0.305	0.456	0.603
	50 W	141.1 ± 18.5	143.2 ± 22.4	142.5 ± 16.7	141.5 ± 15.5	0.905	0.946	0.632
	75 W	150.7 ± 17.9	152.6 ± 22.1	157.8 ± 21.6	157.7 ± 19.0	0.921	0.201	0.110
	100 W	166.3 ± 21.3	165.5 ± 21.6	170.8 ± 22.6	173.3 ± 19.2	0.448	0.424	0.082
Diastolic RR blood pressure (mmHg)	Baseline	74.7 ± 8.9	72.2 ± 9.9	74.3 ± 8.5	73.3 ± 9.3	0.151	0.862	0.352
	50 W	79.4 ± 7.7	77.8 ± 11.2	77.9 ± 6.2	79.3 ± 10.4	0.698	0.529	0.485
	75 W	80.1 ± 9.7	80.6 ± 13.9	82.0 ± 9.9	82.0 ± 12.3	0.358	0.408	0.234
	100 W	86.0 ± 9.6	81.4 ± 13.4	85.8 ± 10.2	86.8 ± 10.3	0.475	0.944	0.289

Mean values and standard deviations for the parameters surveyed at the different exertion levels for: no mask; cloth mask (Article 453–3 333/090–001, made of microfilament fabrics, Karl Dieckhoff GmbH & Co. KG, DIN EN 13795); surgical face mask (Sentinex Lite Surgical Face Mask, L&R, performance level Type II 57 according to DIN EN 14683); FFP2 mask (Aura respirator 1862 + FFP2, EN 14683, EN 149: 2001 + A1: 2009); p-values < 0.05 are highlighted in bold. As the study had a relatively small number of participants and no defined primary endpoint, the p-values are purely descriptive and were not adjusted for multiplicity. To avoid exhaustion-related bias, the differences to the baseline values for all parameters per watt level and mask type were determined for each participant (e.g. PtcCO₂ at 50 watts without mask – PtcCO₂ baseline without mask). Statistical analysis results were relative to the differential values.

perceived exertion and the tightness of a mask seal, it cannot be ruled out that the measured increase in PtcCO₂ with the FFP2 mask caused the high level of perceived exertion and subjective discomfort, although it remains unclear to what extent somatic or psychological factors play a role. Protective measures can only be sufficiently implemented in the workforce and the general population if they are widely accepted, and this should be taken into account when planning mask use in hospitals.

In summary, a short-term high workload while wearing the common mask types used in hospitals seems to have measurable but clinically irrelevant influence on the blood gases and vital parameters in people of working age who have no known underlying cardiopulmonary disease. Direct effects of an increase in CO₂ on the described symptoms, or health risks from long-term mask wearing, cannot be ruled out but are rather unlikely given the described relationships.

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Conflict of interest statement

The authors declare that no conflict of interest exists.

Manuscript received on 15 June 2020, revised version accepted on 20 August 2020.

Translated from the original German by Dr. Veronica A. Raker.

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Cite this as:

Georgi C, Haase-Fielitz A, Meretz D, Gäsert L, Butter C: The impact of commonly-worn face masks on physiological parameters and on discomfort during standard work-related physical effort. *Dtsch Arztebl Int* 2020; 117: 674–5. DOI: 10.3238/arztebl.2020.0674